HYDRATION CHARACTERISTIC OF MIRHA IN NORMAL AND FOAMED CONCRETES

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CERTIFICATION OF APPROVAL

Hydration Characteristic of MIRHA in Normal and Foamed Concretes

By

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CERTIFICATION OF ORGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ADILAH BINTI MOHD ZAWAWI

ABSTRACT

Rice husk become one of the demanding waste problem since it is the by-products of paddy milling industries. This by-product is actually contain amorphous silica after undergoes controlled burning process. This silica can enhance the quality of concrete through the formation of calcium silicate hydrate (C–S–H) gels. To produce best quality of rice husk ash (RHA), a proper burning procedure should be determined. Universiti Teknologi PETRONAS (UTP) provide a microwave incinerator as a machine to burn RHA with a proper burning procedure. Foamed concrete is a lightweigth concrete. On the other hand, this concrete has low density which contribute to low strength. Silica in RHA has the capability to convert calcium hydroxide (CaOH) to C–S–H which will increase the strength of concrete. This research is to investigate the optimum burning temperature for UTP microwave incinerator in order to identify the best quality of Microwave Incinerated Rice Husk Ash (MIRHA). In addition, studies is also conducted on the hydration characteristics of foamed concrete. X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and compressive strength are conducted to identify the best quality of MIRHA. From the test conducted, 300 °C is obtained as optimum burning temperature. Then MIRHA used to replace 5%, 10% and 20% of cement content in concrete with 0.42 and 0.80 w/c. Then, the best w/c of normal concrete is obtained and used in foamed concrete. The hydration characteristics of foamed concrete determined by using non-evaporable water test. 20% of MIRHA added in concrete determined as the highest non-evaporable water content in foamed concrete so do the compressive strength.

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CHAPTER 1
INTRODUCTION

1. INTRODUCTION

Concrete composed of Ordinary Portland Cement (OPC), aggregates and water. OPC is expensive in the current market and not friendly to nature. One tonne of cement produced is associated with similar amount of Carbon dioxide (CO_2) will be discharged into the atmosphere [1]. Rice Husk Ash is one of the Cement Replacement Material (CRM) that can be one of the solutions for this problem and can be used in building technology. When producing rice, rice husk will be thrown away as waste material. This can cause pollution when talk about disposing the waste. Rice husk is also recognized as a potential source of energy. Moreover, 20% of the ash contain 95% of amorphous silica that make the rice husk ash can be utilized economically [2]. This rice husk burning under controlled conditions to produced the best quality of the ash to utilize the resultant ash as building material [1].

By using lightweight concrete, the self weight of the concrete will be reduced. This will bring a lot of advantages for example cost reduction. When combining CRM and foamed concrete (lightweight concrete), it can be economical and environmental friendly.

Hydration process is a process which can predict the performance of concrete. RHA combined with cement in presence of water harden due to pozzolanic reaction [3]. This reaction occurs between silica and alumina of the pozzolana and calcium hydroxide [3]. Non-evaporable water test is one of the methods to determine the hydration characteristic of concrete.

1.1 Problem Statement

Ground granulated blast furnace slag (GGBFS), Fly Ash, Silica Fume and Rice Husk Ash (RHA) are some of waste materials that can be used in mortar and concrete production. These materials are finer than cement and also called as cementitious materials. This material is a pozzolan which will have pozzolanic reaction. RHA contains high amount of silicon dioxide and also highly reactive pozzolanic material when produced under controlled burning of rice husk. High content of amorphous silica and high specific area from porous structure of fine particles of RHA affect the reactivity of rice husk ash.

This research focused on the burning procedure to obtain RHA that is highly reactive so it can be used as cement replacement material to improve building technology. Not only that, this is also due to environmental concern. By using RHA, the production of cement can be reduced as well as CO_2 in air. In addition, if there is no proper burning process of RHA, this can reduce quality and quantity of a product. Plus, this also can make environment polluted. So, high temperature microwave incinerator in Universiti Teknologi PETRONAS (UTP) has been used which produce best quality of rice husk ash which is called MIRHA (Microwave Incinerated Rice Husk Ash). No research had been done with the burning temperature profile of this equipment. So the author used this opportunity to do this research. After determined the burning temperature profile, the optimum temperature of RHA can be observed. As a consequent, best quality of MIRHA will be produced.

Then, the optimum temperature of RHA will be used in mortar and the hydration of the mortar will be determined. The hydration phenomenon can describe the development of strength and durability on concrete. The combination of water and cement will produce calcium silicate which will increase the bonding between them to increase the strength of the concrete. There are two types of water involved which are evaporate and non-evaporate water. The non-evaporate water is where the hydration phenomenon occurs.

The study of water in foamed concrete with rice husk ash (RHA) as pozzolanic material is particularly interesting which water content can be used to follow the behavior of pozzolanic materials. Since pozzolanic materials are commonly included in high-performance and high strength concrete, a deeper understanding of their behavior will encourage their incorporation in concrete, and enable the production of more durable and efficient concrete structures.

1.2 Objective

There are two main objectives in this project which are :

i. To identify the optimum burning temperature for UTP Microwave Incinerator

ii. To ascertain the hydration characteristics of MIRHA in foamed and normal concrete

1.3 Scope of Study

In this study, the sources of rice husks are taken from rice milling plant in Malaysia, Bernas. By using UTP microwave incinerator, the temperature of burning rice husk is varies which is at 300 °C, 400 °C, 500 °C, 600 °C and 800 °C. To determine the optimum temperature of burning, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and compressive strength are used.

Microwave Incinerated Rice Husk Ash (MIRHA) with optimum burning temperature is used to replace cement with 5%, 10% and 20% of cement content in concrete. Concretes characteristic analyzed by using compressive strength and non-evaporable water test at 3, 7 and 28 days. Method used for non-evaporable water test based on oven dry/furnace ignition methods.

Portafoam Model LCM is the equipment used to produce stable aqueous foam for production of foamed concrete. The foam agent used was LCM consists of hydrolyzed proteins and it is manufactured in Malaysia.

CHAPTER 2
LITERATURE REVIEW

2. LITERATURE REVIEW

This chapter describes the background that lead on the development of rice husk ash in concrete. There are many researchers have been conducted this study. Therefore, the available published literature on RHA, hydration of pozzolan and foamed concrete is briefly reviewed throughout this chapter.

2.1 Agricultural Waste Material

Agriculture is one of the important sectors in Malaysia. Production of food will be increase due to increasing the population of citizen. Production of food is actually contributed in producing the waste material. For example, sugar cane in sugar industries and rice husk as a by product of paddy [4,5].

Tonnes of waste material will be produced every year. The disposal of this material will account a big problem not only to country but also to environment. Some researcher had found solution for this problem. According to Mittal, A., Kurup, L., and Gupta, V, de-oiled soya can be used as the potential absorbents for the removal of hazardous part from wastewater [6].

Meanwhile, cement industries provide opportunities to reduce this problem. Rice husk [5], sugar cane waste [4] and tobacco waste [7] are the solution for this problem and can partially replace cement as Cement Replacement Material (CRM).

2.2 Cement Replacement Material

Cement, aggregate and water are 3 basic material when producing concrete. Cement had been used years ago. So, the raw material of cement is decreasing in this world. Then, Cement Replacement Material (CRM) is one of the solutions for this problem. These materials actually can replace part of the cement such as fly ash (FA), ground granulated blast furnace slag (GGBFS), silica fume (SF), and rice husk ash (RHA). Mainly, these products are from industrial by-product.

So, CRM can actually can safe the nature because of used of these industrial waste materials [1]. In facts, when a tonne of cement produces, one tonne of carbon dioxide will be discharged into the atmosphere [1]. Plus, by adding CRM into concrete they can help in advancement of hydration phenomenon. Furthermore, they can make the hydration product much better. Actually, CRM is commonly used in concrete industry. This proves based on the highly demand on this product in the 1970s [1].

2.2.1 Rice Husk

Rice is one of the important food in Asia especially Malaysia. This proves when statistic shows "90% of world's rice conquered by South and South East Asia" [2]. Paddy grain consist of 2 parts which are rice kernel, the inner part and the outer part, husk which cannot be eaten as shown in Figure 2.1. Because of that reason, it should be removed and become an agro-waste material.

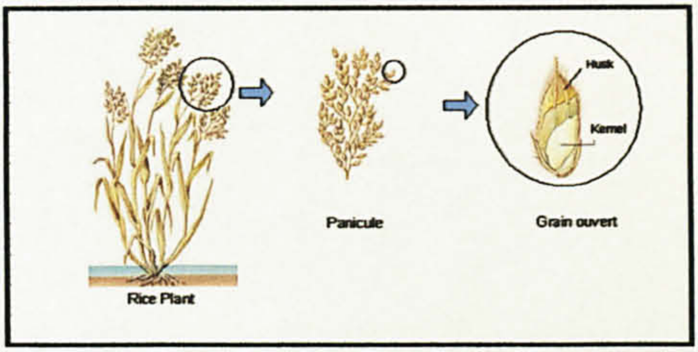

Figure 2.1 : Rice Plant Basics [9]

In fact, about 20-22% of rice milling consist of rice husk [5,10]. It depends on the rice plant, location, season and cultivating methods. So, tonnes of natural waste product produced in this world. Problem when a lot of waste product is how to dispose them. In Malaysia especially in Kedah, Perak and Selangor where the production of rice is high, the farmers just burn the husk in the paddy field. This method is actually caused another problem which is natural damage due to open burning. Based on some researchers, rice husks content of a very high silica and slow firing at a temperature of 500-700 °C results in an amorphous material with a porous structure [1,10]. In facts, rice husk divided by 2 parts which are organic and inorganic mineral matter. Cellulose, lignin, pentosans and a small amount of protein and vitamin are in the organic matter. While silica is in the inorganic mineral matter.

2.2.2 Rice Husk Ash

In this research, the author used rice husk from rice milling Bernas, Malaysia. Years ago, research on Rice Husk Ash (RHA) had begun. According to Mehta [11] in 1978, he investigated how the pyroprocessing effect on the pozzolanic reactivity of RHA. In 2002, Nehdi, Duquette and Damatty [12] investigated the effect of RHA in performance of concrete. In their research, the effect of different burning temperature of RHA also included same like the first objective of the author in this research. The different is how the material burned. In 2008, Memon, Shaikh and Akhbar [9] explore effect of RHA in production of low cost self compacting concrete in Pakistan construction industry.

2.3 Rice Husk Ash

2.3.1 Burning Procedure

According to some research, high amount of silicon dioxide can be find in RHA [2,5]. There are 2 types of burning the RHA which are which is burning if RHA had been setting up in a machine and uncontrolled combustion which is burning without setting up the temperature-time condition procedure. A good quality of RHA can be obtained by controlled combustion [2]. In this research, the author used the controlled combustion machine which is high temperature microwave incinerated in

Universiti Teknologi PETRONAS (UTP), Malaysia. According to [2], non-crystalline phase or amorphous phase form when the controlled combustion at temperature below 600-700 °C. The next phase which is crystalline phase will form after the temperature is higher than 850 °C [8].

2.3.2 Characteristic of RHA

Mineral composition of rice husk ash

To produce a good quality of RHA, the RHA must be in partially crystalline state [12]. In this state, it consists of amorphous and α-cristobalite compounds. Amorphous state, pure silica can be produced. Based on [2], pure silica with high specific surface area, high melting point and high porosity can be obtained from rice husks. Based on [12], α-cristobalite present in partially crystalline state because the RHA was burnt at temperature higher than 800 °C.

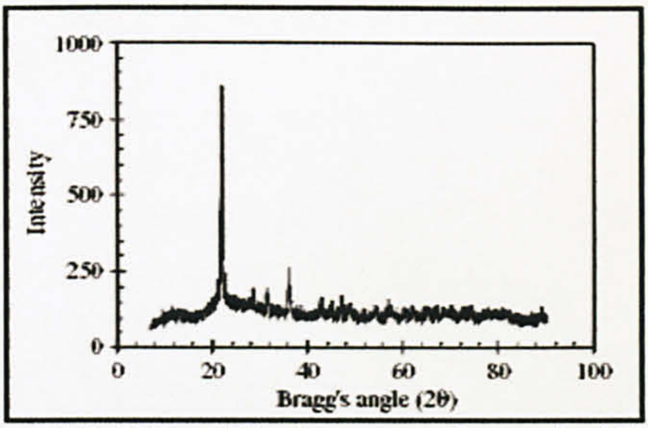

Figure 2.2 : X-Ray diffraction pattern of as-received RHA (all peaks correspond to α-cristobalite) [12]

Based on Figure 2.2, X-Ray Diffraction peaks shows the crystalline forms of silica are absent. The amorphous degree of RHA can defined by the intensity or average height of the diffused band between 15° and 26° 2θ using x-rays. This x-rays generated from a copper target with a nickel filter [11]. According to [13], the peak line of this XRD graph shows the presence of quartz. For different duration of burning or the contamination of sand particles from the pit of burning location can contribute the presence of quartz in RHA.

Chemical composition of rice husk ash

The chemical composition of RHA can be determined by using X-Ray Fluorescence (XRF). This analysis will reveals silica as the main component. Silica content of RHA mostly between 80 – 95% [12].

Table 2.1 : Chemical composition (%, by mass) of the RHA and Portland cement [12]

Material	***RHA***	***Cement***
SiO_2	82.6	20.9
Al_2O_3	0.4	4.2
Fe_2O_3	0.5	5.3
CaO	0.9	63.5
Na_2O	0.1	0.2
K_2O	1.8	0.4
SO_3	0.1	2.4
LOI	11.9	1.1

Table 2.1 shows the chemical composition of the RHA from [12]. These results determined from XRF method and loss of ignition. Content of SiO_2 and LOI in RHA are higher than cement. This will associated with the presence of residual carbon and metallic impurities. The content of K_2O is actually contributes to the formation of black particles during the burning [15]. This black particle formation causes the dark grey color of the ash and the color is darker than cement.

Microstructure of rice husk ash

Scanning microscopy (SEM) is the method to display the microstructure of RHA image. The SEM test is to confirm the presence of quartz in the XRD. RHA is highly porous gives high specific surface.

2.3.2 Hydration Mechanism

When these 'supplementary' materials combined with Portland cement, it is called blended Portland cement. This combination "may undergo hydration on its own and contribute to the strength of the concrete" [1]. Plus, this combination reacts chemically with calcium hydroxide release from the Portland cement hydration process to form cement compounds. Used of CRM is actually can reduce cost of construction. This is due to the increasing value of the cement. Other than that, CRM can increase the durability of concrete. But, when the proportion of the blended Portland cement is varies, the strength and durability of concrete also will be varies [8].

2.4 Microwave Incinerator

To produce amorphous RHA with high pozzolanic reactivity, this microwave incinerator is proposed. This can enhance the properties of concrete. In addition, this incinerator also can avoid environmental problem caused by open burning.

2.4.1 Procedure

Microwaves are part of the electromagnetic spectrum. This wave is located between 300 MHz and 300 GHz [17]. Microwave heating is different than the conventional method of heating material. Conventional heating transfer mechanisms of convection, conduction or radiation to thermal energy while mechanism of microwave heating is when energy transferred electromagnetic field into thermal energy throughout the entire volume of the material.

2.5 Hydration Phenomenon

2.5.1 Hydration of Cement

There are 4 main compounds of Portland cement which are Tricalcium silicate (C_3S), Dicalcium silicate (C_2S), Tricalcium aluminate (C_3A) and Tetracalcium aluminoferrite (C_4AF). In presence of water, these compounds will form products of hydration [1]. Presence of sulfates of sodium, potassium and calcium which are in clinker sulphate and also gypsum are added to form cement powder. When cement and water are combined together, an exothermic reaction will be produced. There are two ways reaction will produced which are true reaction of hydration which some molecules of water takes place and the other one is hydrolysis [1]. When this combination reacts, it will yield to form a complex microstructure consists of hydrate gel and carbonate phases. Figure 2.3 shows schematic represents the formation and hydration of Portland cement [1].

COMPONENT ELEMENTS

O_2	Si	Ca	Al	Fe

↓

COMPONENT OXIDES

CaO	SiO_2	Al_2O_3	Fe_2O_3

↓

CEMENT COMPOUNDS

C_3S	βC_2S	C_3A	C_4AF

↓

PORTLAND CEMENTS

Various types of Portland Cement

↓

HYDRATION PRODUCTS

gel	$Ca(OH)_2$

Figure 2.3 : Schematic representation of the formation and hydration of Portland Cement [1]

2.5.2 Reaction

In cement compound, there are consist of C_3S which is known as alite, and C_2S as belite. These compounds called impurities make the properties of the calcium silicate hydrates stronger. Succession of chemical reactions of Portland cement hydration converted the anhydrous phases of Portland cement into hydrated phases. Here are the general equation of the reaction in equation 2-1 through 2-4 below [1] :

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3CH \qquad 2\text{-}1$$

$$2C_2S + 4H \rightarrow C_3S_2H_3 + CH \qquad 2\text{-}2$$

$$C_3A + 6H \rightarrow C_3AH_6 \qquad 2\text{-}3$$

$$C_4AF + 2CH + 10H \rightarrow C_3FH_6 + C_3AH_6 \qquad 2\text{-}4$$

Setting and development of "early" strength (first 7 days) is responsible by alite. Different with belite, it responsible to strength at later times that's why the reaction is slow. When cement reacts with water, the final reaction basically is like this below equation [1] :

Tricalcium silicate + Water → Calcium silicate hydrate + Calcium hydroxide + heat

$$2Ca_3SiO_5 + 6H_2O \rightarrow 3CaO.2SiO_2.4H_2O + 3Ca(OH)_2 + 173.6\ kJ$$

Based on this equation, presence of water release calcium ions, hydroxide ions, and a large amount of heat [1]. Plus, product of C_3S, alkaline hydroxide increases the pH reading [1]. Slowly, calcium and hydroxide ions will be saturated. Once this reaction occurs, calcium silicate hydrate formed [1]. Reaction of tricalcium Silicate to calcium and hydroxide ions increases the heat of hydration.

C – S – H which is known as calcium silicate hydrate is one of the product in cement hydration. This product is the main source of strength of concrete. This is because it grows as a mass of interlocking between the cement, water and aggregate that provide the strength of a concrete.

Other than that, Calcium hydroxide, $Ca(OH)_2$ also product of cement hydration [1]. In hydrated cement system, $Ca(OH)_2$ is most soluble phases in that system. In Jacques Marchand, Dale Bentz, and Eric Samson research [18], they found out that Calcium hydroxide make the porosity of hydrated cement paste increases. Due to this increases, it will affect the material transport properties in the process. In good side, this increase makes the results in numerical simulations affect the performance in deionized water of calcium leaching. Calcium hydroxide also used C – H term is mostly in alite hydration. In C – H, it contains Ca and Si which the ratio of both mineral is 3:1 while in C – S – H have 2:1 ratio. As a result, production of C – H is because of the excess of lime.

Calcium Sulfoaluminate or in other word, ettringite contain in product of cement hydration. Ettringite is usually form within 24 hours after combination of sulfur in cement. This product effects the increases in fresh, plastic concrete. Ettringite can reform in less confined locations when the concrete exposed to water in a long time period [19]. The present of rod-like crystals can be observed by using microscopic test.

Other than that, monosulphate also product of cement hydration. This product is form after a few days. It also replaces ettringite and both of ettrigite and monosulphate are different proportions of C_3A, $CaSO_4$ (anhydrite) and water compounds.

C_2S, Dicalcium silicate also involved in hydration phenomenon. It is similar like tricalcium silicate but it is slower because this compound reacts at late times and less reactive. The reaction of hydration is based on the equation below [1] :

Dicalcium silicate + Water → Calcium silicate hydrate + Calcium hydroxide +heat

$$2\ Ca_2SiO_4 + 5\ H_2O \rightarrow 3\ CaO \cdot 2SiO_2 \cdot 4H_2O + Ca(OH)_2 + 58.6\ kJ$$

Tricalcium aluminate (C_3A) and Tetracalcium aluminoferrite (C_4AF) also the major component in hydration. C_3A make the concrete quickly hydrates and harden. To improve C_3A hydration gypsum and can produce high amount of heat plus can contribute to early strength. C_4AF not really contribute to strength but it hydrates rapidly. Color of cement basically because of this compound.

2.5.3 Pozzolanic Reactivity

A reaction which is chemically reaction between a pozzolan (S) and calcium hydroxide (CH) in presence of water (H) is defined as pozzolanic reaction. It can be generalized by the simplified equation shown in equation 2-5 [28].

$$\text{Pozzolan} + CH + H \rightarrow C\text{-}S\text{-}H \qquad 2\text{-}5$$

Water and pozzolanic reactivity demand are two main parameters of RHA. RHA reactivity depends on the amorphous silica content on its porous structure. The reactivity decreases if the porous structure gets minimized by milling process in an effort to reduce particle size.

By using pozzolan material in cement, there will be a lot of advantages. Pozzolan has the ability to convert calcium hydroxide to calcium silicate hydrate. Then, the capillary voids will either eliminate or reduced in size. This phenomenon will improve cement-concrete material such as strength and durability of the hydrated paste. Pozzolan is also an economical because most of pozzolans are cheaper than cement. Pozzolan can be used as cement replacement material which partially replaces cement. This promotes the use of waste products and thus conserves energy and resource.

2.5.4 Hydration Mechanism of Paste by RHA

Studying the hydration of RHA paste is significant exploring its superiority to improve the properties of the paste, mortar and concrete. According to Hwang and Chandra [29], the first 8 hours for hydration process in RHA paste is similar to the behavior of OPC paste with the growth of calcium hydroxide, $Ca(OH)_2$. During this period, penetration resistance maybe primarily due to the formation of $Ca(OH)_2$ crystal. In addition, at the surface of RHA maybe due to the adsorption by cellular structure of RHA. Bleeding water also will significantly reduce in such case. The pozzolanic reaction inside cellular spaces enhanced by the adsorption of water. The pozzolanic reaction in RHA with $Ca(OH)_2$ to form C-S-H gel and solid structure after 40 hours. This means the RHA fills the finer pores and reduces the permeability, which may be beneficial to the durability [29].

2.5.5 Water

2.5.5.1 State of water

Water is the most important ingredient when comes in cement paste or concrete. Basically the function of water is to make the cement harden the hydration. Calcium hydroxide crystals, unhydrated cement compounds and water in the pore structure are the main product of hydration process [20]. A.M. Neville [1] in his research said "Water in hydrated cement actions in different degree of firmness. At one extreme, there is free water; at the other, chemically combined water forming a definite part of the hydrated compounds. Between these two categories, there is gel water held in a variety of other ways". In other words, there are 3 types of water are distinguished which are free water, chemically bonded water and gel water.

Capillaries larger that 50 Å is where the free water or capillary water presents [20]. Furthermore, it is beyond the range of the surface forces of the solid phase [20]. Gel water also known as absorbed water is divided by two which are surface adsorbed water and interlayer water. Close to solid surface where the water is react by the surface forces of gel particle, surface absorbed water is present [20]. While in interlayer water, C – H – S will combined with water [20]. In water, there is a monomolecular water layer that react with C – H – S by hydrogen bonding. The other part of water, which is chemically bound water, is defined as some part of cement hydration where only can demolish by thermal dehydration.

According to A. M. Neville [1], no specific technique to measure the distribution of water. Based on 3 types of water, there are divided by 2 categories which are evaporated and no-evaporated water [1]. Evaporated water is where the water reacts with surface forces between the capillaries. Other than that, it is to measure how much water can remove by drying material [1]. Capillary water and gel water include in evaporated water. Non-evaporated water is under chemically bound water [1]. During cement hydration, the water is chemically combined. The other thing is it cannot be removed by drying it [1].

2.5.5.1 Non-evaporable water

Chemically combined water is an important type of water to measure because it used to quantify the hydration of concrete. Non-evaporable water means the amount of water that is not removed by certain drying procedure. The goal of measuring non-evaporable content is to get the amount of chemically bound water. The drying method used in non-evaporable water is to eliminate the free and adsorbed water and to leave only the chemically bound water. The experimental program for non-evaporable water will be explained in chapter 3.

2.6 Foamed Concrete

2.6.1 Introduction

Foamed concrete is one of the lightweight concrete and it is a porous concrete. This concrete is different than the conventional concrete. Furthermore, this concrete is lighter and it is not use coarse aggregates into the mix. Water, cement, fine aggregates and foam are the ingredients of this foamed concrete. The steady foams by suitable foaming agent produce homogeneous void structures in foamed concrete [30]. This foamed concrete is usually used in almost every part of building like wall panel and roofing.

2.6.2 Characteristic

Strength and density of foamed concrete is different with the conventional concrete. The user would specify a certain compressive strength and the water/cement would be adjusted to meet specification for the ordinary concrete. When foamed concrete is specified, it is normally not only the strength, but also the density. Exponentially, decreasing the compressive strength, reduces the concrete density but greater quantity of air bubbles present in the cementations microstructure [31].

If not enough water added to mixture, the water will not sufficient for the initial reaction of the cement and the cement will withdraw water from the foam, causing rapid degeneration of foam. While if it is extra water is added, segregation will takes place which will cause a variation in density.

2.6.3 Advantages

There are some advantages by using this concrete. For example, this concrete is a long-life concrete because it can increase the solidity of a concrete. Other than that, this concrete also is economical in terms of transportation because coarse aggregate is not use. So, it can reduce man power.

This concrete high in workability, compacting and leveling. This shows this concrete is good in flow ability, self-compacting and self-leveling nature. In addition, by using foamed concrete at site, noise from the site will reduced and it also can improves the construction environment in the absence of concrete vibrating equipment.

This concrete used foam as one of the ingredient in mixing. Actually, foam is very low water absorption. For conventional concrete, the higher the water content, the higher the water absorption. But for foamed concrete, its only can absorb lower amount of water.

CHAPTER 3
METHODOLOGY

3. PROGRAMME OF WORK

Detail of the experimental program used in this research will be carry out in this chapter. First, the author will introduce the material used in this research. Then, followed by the explanation on the experimental design and laboratory for all experiments.

3.1 Material Selection

3.1.1 Rice Husk Ash

Rice milling plant Bernas, Malaysia is the source of rice husk that the author used in this research [17]. To reduce moisture content of Rice Husk Ash (RHA), Bernas had dried the rice husk under direct sunlight [17]. This can reduce the amount of smoke produced when burning the rice husk. In addition, it also can reduce air pollution.

Rice husk ash production

In this research, the author used new equipment from Universiti Teknologi Petronas (UTP), high temperature microwave incinerator. The raw rice husk ash is shown in Figure 3.1 and Figure 3.2 shows the microwave incinerated equipment used in this research.

Figure 3.1 : Raw rice husk

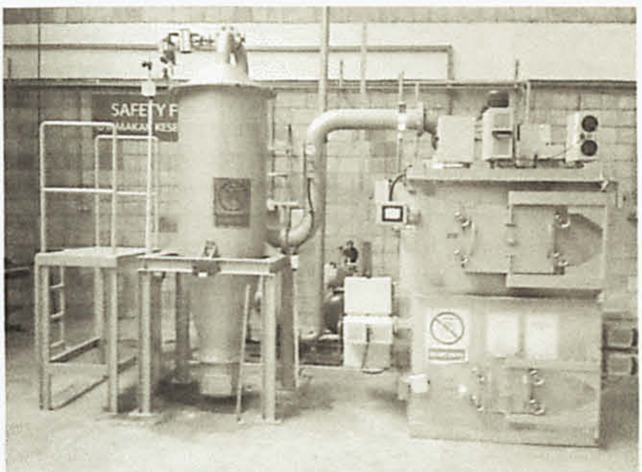

Figure 3.2 : Automatic Microwave Incinerator

To achieve the first objective of this research, the author varies the temperature of rice husk burning to get the optimum strength of pozzolanic activity. Temperature used are 300 °C, 400 °C, 500 °C, 600 °C and 800 °C. Figure 3.3 shows the rice husk ash after burning into microwave incinerator called MIRHA (Microwave Incinerated Rice Husk Ash).

Figure 3.3 : MIRHA after burning

To form higher strength of concrete, RHA must be finer than the cement. So that RHA can easily fill between the free spaces of cement. So, the RHA need to grind in a equipment called Los Angeles (LA) Abrasion machine. Figure 3.4 shows the LA Abrasion machine that the author used provided by UTP and Figure 3.5 shows the MIRHA after grinding.

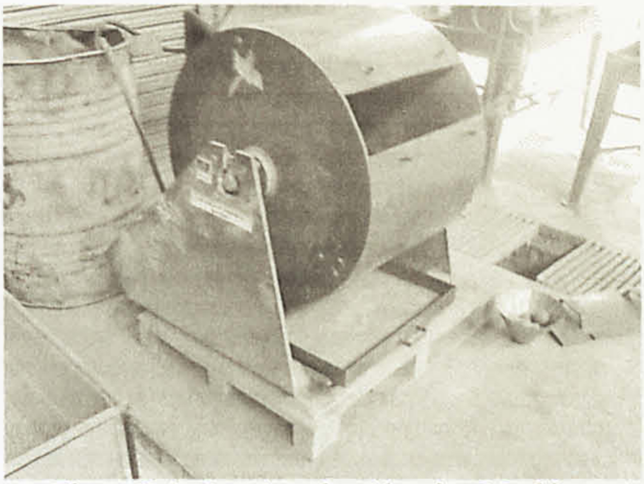

Figure 3.4 : Los Angeles Abrasion Machine

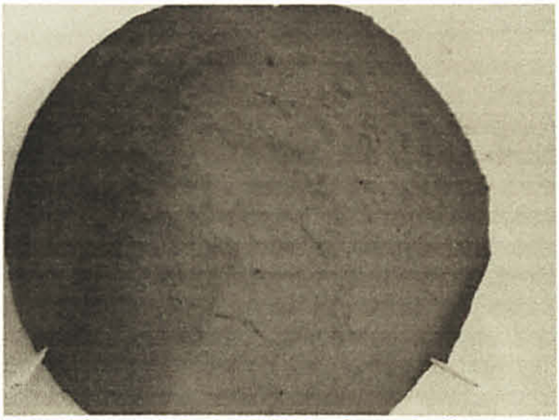

Figure 3.5 : MIRHA after grinding

Silica is the composition in RHA that effect the strength of the concrete. Higher the silica, higher the strength. To find the presence of silica, a test had conducted which is X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF).

Composition of rice husk ash

Two types of composition of RHA should be analyzed which are chemical and mineral composition. X-Ray Fluorescence (XRF) test conducted to identify the oxide composition compound of RHA. Powder sample of 300 °C, 400 °C, 500 °C, 600 °C and 800 °C of RHA are tested. Based on this test, silicon dioxide content can be determined [5].

For Mineral composition of RHA can be determined by using X-Ray Diffraction (XRD) test. Same like XRF test, all powder sample of RHA are tested. After two hours the test is running, a graph patterns of XRD analysis will be produced. This graph shows the phase of the material whether in amorphous, partially crystalline or crystalline state. Figure 3.6 shows the XRD equipment used in UTP.

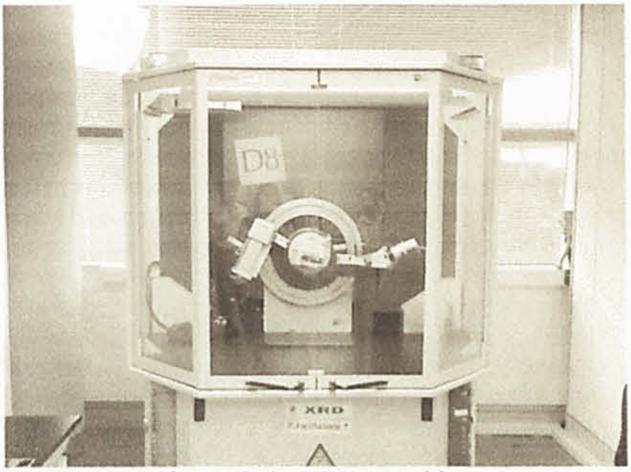

Figure 3.6 : XRD machine

Microstructure of rice husk ash

To see how the structure or pore microstructure of RHA, Scanning Electron Microscopy (SEM) test conducted. This test also can see the fines of each sample used. Sample used that used in this sample are raw rice husk, 300 °C, 400 °C, 500 °C, 600 °C and 800 °C of RHA. In this research, the author had used the equipment provided by UTP and the machine type is LEO 1430VP. Through this test, picture of the microstructure will be printed and can see the different microstructure. Between the RHA sample, different porous of RHA can be determined. SEM equipment shown in Figure 3.7.

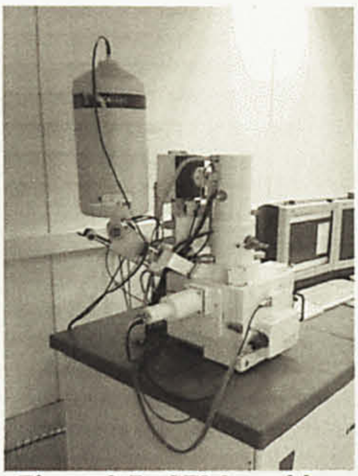

Figure 3.7 : SEM machine

3.1.2 Ordinary Portland cement

In this research, Ordinary Portland Cement (OPC) had been used. This is because this cement can be done in normal hydration process without any admixture adding to the concrete.

3.1.3 Fine Aggregate

Fine aggregates that had been used in this research is sand. This material was obtained from the deposit of Tronoh, Perak, Malaysia. Sand which the size is about 15 μm had been used to do mortar. Basically, when aggregate is use in mixing, the aggregate must washed before use to achieve Class A Quality [22]. But when the aggregate is less than 75 μm, it shall not to be washed and its proven by engineer [22]. Figure 3.8 and Figure 3.9 shows the sieve equipment and sand that had been sieved.

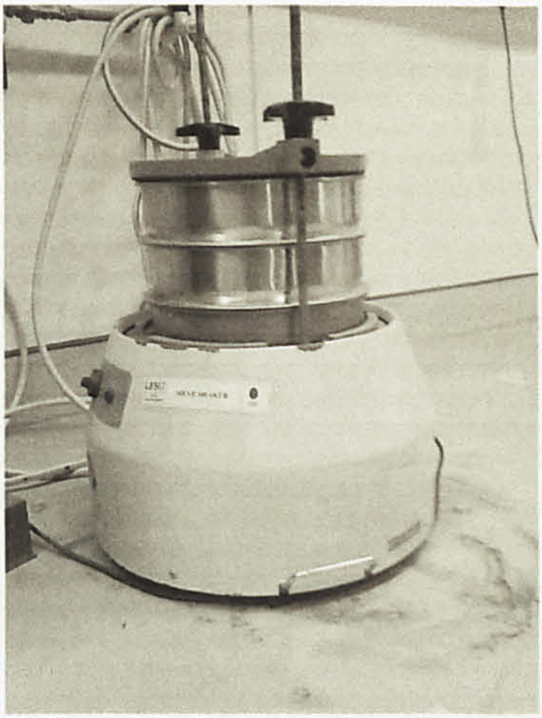

Figure 3.8 : Sieve analysis equipment

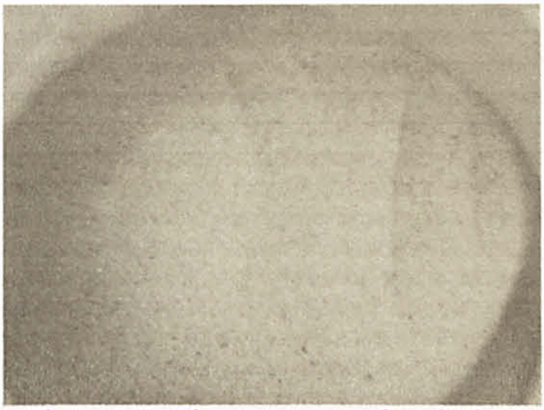
Figure 3.9 : Fine aggregate after sieving

3.1.4 Water

Water is the important ingredient when talk about concrete. Usually, water/cement (w/c) ratio in concrete or mortar ranges from 0.4 to 0.8 depends on the composition of the cement [21]. The water was obtained in UTP laboratory.

3.1.5 Superplasticizier

To improve workability of a mortar or concrete, superplaticizier is a must. Superplasticizier is a chemical admixture of high range water reducer or dispersants. There are many types of chemical admixture used as superplasticizier but in this research, the author had used Sulfonated Naphthalene Formaldehyde condensate.

3.1.6 Foam agent

To form foamed concrete, foam is very important. Foam is the combination of foam agent and water by ratio of 1:30 (by volume).

3.2 EXPERIMENTAL DESIGN

In this research, the author had done 2 phases of mixing. The first phase is to determine the optimum temperature of MIRHA as shown in Table 3.1. After the optimum temperature of MIRHA determined, the second phase will be conducted by using the optimum temperature of MIRHA. The second phase is to determine hydration process as shown in Table 3.2 until Table 3.5. In Table 3.2 and Table 3.3, the water/cement (w/c) ratio is different because the author wants to know the effect of w/c ratio by adding MIRHA. Then, the best w/c will be used in foamed concrete mixing.

Volume sample: 2.0625 liter

Cube 50 mm : 0.125 liter

No. of sample : 7 cubes per mix

Table 3.1 : Mix Proportion to determine optimum temperature of MIRHA

MIRHA	Cement (%)	Cement (kg)	Water (%)	Water (kg)	Dry fine aggregate (%)	Dry fine aggregate (kg)	MIRHA (%)	MIRHA (kg)	*SP (%)	*SP (kg)
No MIRHA	23.6	1.125	11.4	0.545	11.4	3.094	0.000	0.000	0	0.000
300 ° C	21.8	1.013	11.7	0.545	11.7	3.094	2.4	0.113	1% of water	0.055
400 ° C	21.8	1.013	11.7	0.545	11.7	3.094	2.4	0.113	1% of water	0.055
500 ° C	21.8	1.013	11.7	0.545	11.7	3.094	2.4	0.113	1% of water	0.055
600 ° C	21.8	1.013	11.7	0.545	11.7	3.094	2.4	0.113	1% of water	0.055
800 ° C	21.8	1.013	11.7	0.545	11.7	3.094	2.4	0.113	1% of water	0.055

* Note that SP is Superplasticizier

Volume sample: 2.0625 liter

Cube 50 mm : 0.125 liter

No. of sample : 3 cubes per mix

a) Cement paste + water (w/c=0.42) + MIRHA with optimum temperature on strength index activity

Table 3.2 : Mix Proportion to determine hydration process for cement paste w/c=0.42

MIRHA (%)	Cement (kg)	Water (kg)	MIRHA (kg)
0	3.516	1.230	0.000
5	3.340	1.230	0.176
10	3.164	1.230	0.352
20	2.813	1.230	0.703

b) Cement paste + water (w/c=0.8) + MIRHA with optimum temperature on strength index activity

Table 3.3 : Mix Proportion to determine hydration process for cement paste w/c=0.8

MIRHA (%)	Cement (kg)	Water (kg)	MIRHA (kg)
0	2.168	1.734	0.000
5	2.060	1.788	0.176
10	1.951	1.842	0.352
20	1.734	1.950	0.703

c) Cement paste + water (w/c=0.42) + Foam + MIRHA with optimum temperature on strength index activity

Table 3.4 : Mix Proportion to determine hydration process of foam cement past w/c=0.42

MIRHA (%)	Cement (kg)	Water (kg)	MIRHA (kg)	Foam (liter)
0	3.516	1.230	0.000	0.8
5	3.340	1.230	0.176	0.8
10	3.164	1.230	0.352	0.8
20	2.813	1.230	0.703	0.8

3.3 Experimental Programme

3.3.1 Specimen Preparation

Before starting the experiment, preparation of specimen is important. This can make the process when starting the experiment smoothly. In each of experiment, make sure that all of the mixtures are consistent and if not noted them.

3.3.2 Mixing Process

To produce mortar, a mixing procedure had been used. In this research mixing machine had been used as shown in Figure 3.6. Mortar is done by the procedure explained. Based on ASTM C305 [24], first, all the mixing water placed in the bowl. Then, cement added into the bowl together with water. Mix them at slow speed (140 rmp) for 30s. While mixing in slow speed, slowly put sand over 30s period. After that, stop the mixer before change the speed to medium speed and mix them for another 30s. Let the mortar stand for 1.5 minutes after stop the mixer. Quickly, scrape down the mortar that maybe collected on the side of the bowl during 15s of period. Finally, at medium speed (285 rpm), mix them for 1 minute.

For cement paste, the author had also use the procedure from ASTM C305 [22]. Same like mortars, first thing to do is all the mixing water placed in bowl. To allow 30s absorption, add cement into water. Then, mix them for 30s at 140 ± 5 rpm. Scrape down all paste that maybe collected on the side of the bowl during 15s of period. Finally mix for 1 minute at 285 ± 10 rpm.

3.3.3 Curing Regime

The author had done the curing based on BS EN 12390-2:2000 [23]. After 24 hours casting, the specimens the author placed them for curing at 20 ± 2 °C.

3.3.4 Testing Procedure

After done the mixing, some test should be used to determine whether the experiment should be repeated or not. In this work is highly dependent on the specific details of the testing.

Compression strength

To do this test, compression testing machine provided by UTP had been used as shown in Figure 3.10.

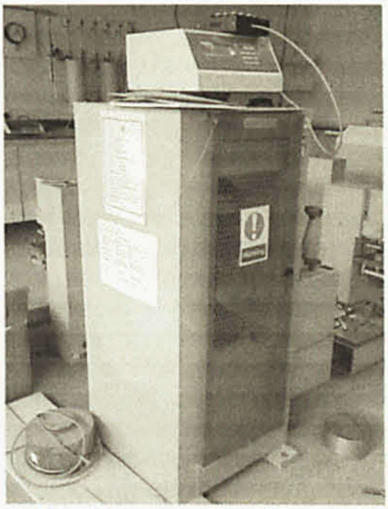

Figure 3.10 : Compression Testing Machine

This test is done to determine the behavior of material under crushing loads. In this research, the author take 3 cubes per mix with 3, 7 and 28 curing days according to British Standard 1881 [24]. The value of compression strength can be determined automatically from the machine or by calculating it by using the equation below which is same like stress-strain equation :

$$F = \frac{P}{A}$$

Where	F	: Compressive strength (N/mm^2)
	P	: Ultimate load (N)
	A	: applied load surface area (mm^2)

Non-evaporable water by oven/furnace

To determine the degree of hydration of cement, non-evaporable water test can be done [25]. There are two types of non-evaporable water tests that the author used which is non-evaporable water by oven/furnace and by TGA. In this experiment, the author only focuses on the oven/furnace test and used the procedure from [26]. After compression test is done, the sample need to crushed to about half of its original height. Sieve the crushed sample into 2mm sieve and put the sample into a crucible. Then, covered the sample with acetone. Acetone is used to eliminate water in the sample. Placed the sample in a clean and dried crucible and heat them in oven at 105 °C for at least 12 hours to removed all evaporable water from the sample.

After 12 hours, weight the sample before place them in furnace for two hours at 1050 °C. Weight the sample again after 2 hours. The use of weighting the sample is to determine the non-evaporable water contents.

4.3.5 Experimental Detail

Table 3.5 shows the summary of experiment that the author used throughout this research.

Table 3.5 : Summary of experiment

Test	Size	No. of sample	Testing Age	Test Purpose	Equipment	Standard	Measurement Unit
Compressive strength	50x50mm cube	Phase 1 : 7(each mix) Phase 2 : 3(each mix)	Phase 1 : 28d Phase 2 : 3,7, and 28d	Compression strength	Compression Testing Machine	BS EN 12390-3:2002	N/mm^2
XRD	Powder	5		Crystalline	XRD equipment	-	-
XRF	Powder	5		Oxide	XRF equipment	-	-
SEM	Powder	6		Microstructure of MIRHA	SEM equipment	-	-
Furnace	Crush sample	Phase 2 : 3(each mix)	2d	Non-Evaporable water	Oven, Furnace	-	-

CHAPTER 4
RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

In this chapter, the author discussed the results obtained in this research. The author will explained how to obtained first objective followed by the second objective. The experiment was conducted starting from burning the Microwave Incinerated Rice Husk Ash (MIRHA) until the non-evaporable water test for foamed concrete.

4.1 MIRHA BURNING ANALYSIS

4.1.1 Burning Temperature Profile

To get the optimum temperature of Rice Husk Ash (RHA), the author had varies the temperature burning which are 300 °C, 400 °C, 500 °C, 600 °C and 800 °C. Approximately 50 kg of rice husk were burned in the UTP microwave incinerator. The machine was then setting to the required temperature. The pattern of temperature burning is in Figure 4.1.

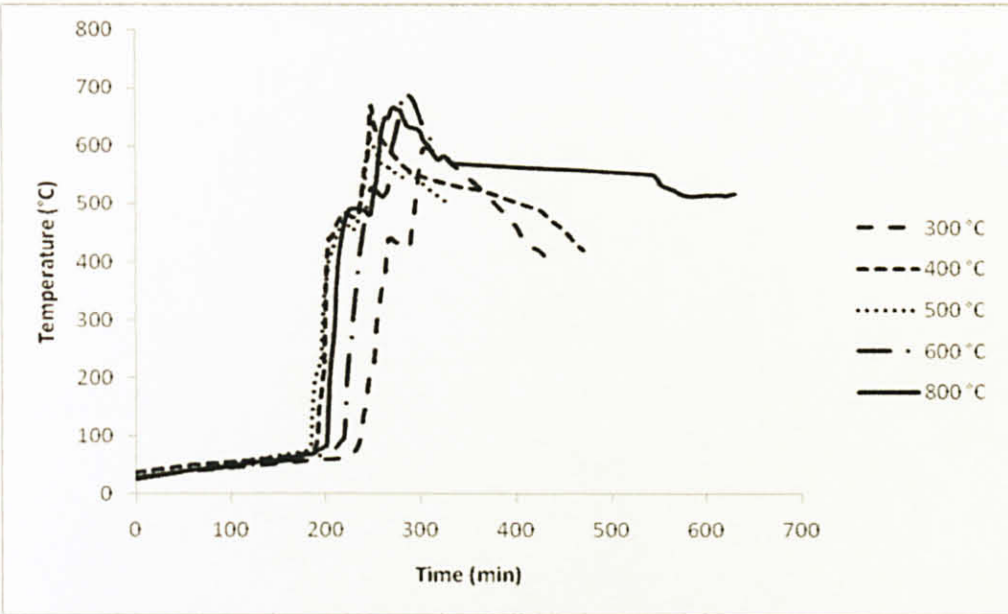

Figure 4.1 : Comparison of different temperature burning of RHA

Based on Figure 4.1, basically the pattern of all graph are almost the same. From the graph, when approximately after 200 minutes of burning, the temperature will increase rapidly and after reach the temperature required, the microwave source will stop but it will continuously burning because heat in the incinerator will not stop. This situation make the temperature continuously increase and after 20 to 30 minutes, the temperature will decrease in about 10 to 20 minutes. Maybe because there is some balance moisture from the rice husks. Then, the temperature will increase back approximately in 1 hour because maybe there are balance heats in the incinerator before it decreases until reach the normal temperature. Because of the graph of temperature burning is almost the same, it shows that the incinerator is stable and in a good condition.

4.1.2 X-Ray Diffraction Analysis

To get the optimum temperature burning of MIRHA, the author decided to do X-Ray diffraction (XRD) test. XRD test is actually to identify the crystalline in the sample. Sample from MIRHA 300 °C, 400 °C, 500 °C, 600 °C and 800 °C of burning are tested. Based on Figure 4.2, MIRHA at all burning temperature, the highest peak of the graph which is at 22° 2θ shows the presence of crystalline. And the gradual dense scatter of the graph shows the amorphous state. So MIRHA is in partially crystalline state. To get a good quality and high strength of MIRHA, the pattern of MIRHA must be in partially crystalline [12]. To make sure which one is the optimum temperature burning of MIRHA, the author conducted another test which is compressive strength.

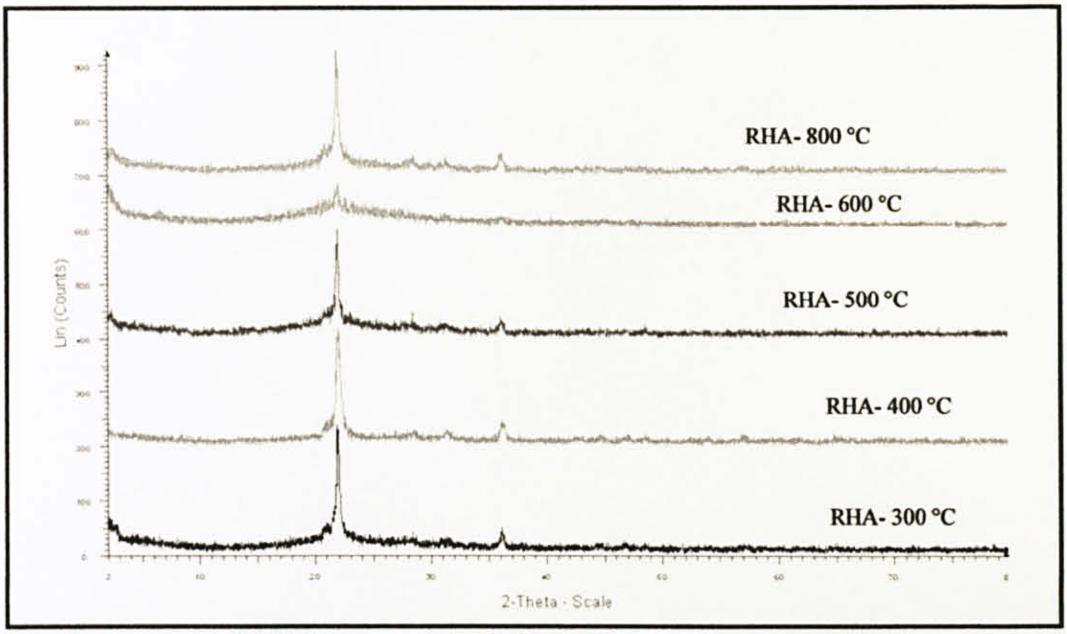

Figure 4.2 : XRD result for each MIRHA temperature

4.1.3 Compressive Strength Analysis

To make sure which one either 300 °C, 400 °C, 500 °C, 600 °C and 800 °C of burning is the optimum temperature burning of RHA, the author decided to compare the compressive strength of mortar when MIRHA for each temperature burning combine with cement. There are 6 batches of mixing including mortar without MIRHA and 7 samples for each batch. The age of each mortar is 28 days. Figure 4.3 shows the graph of the average compression strength in mortar against temperature of RHA in the mortar.

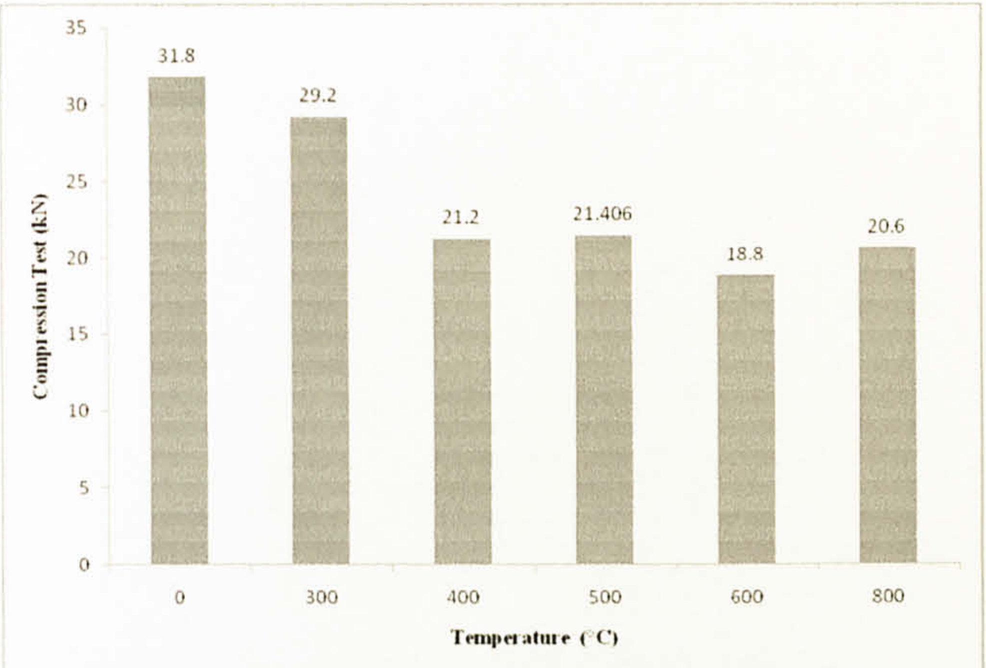

Figure 4.3 : Graph of average compression strength against RHA with different temperature that partially put in mortar

Based on this graph, it shows that burning temperature of MIRHA at 300 °C is slightly higher than the others. So, the author concludes that the optimum temperature burning of MIRHA is at 300 °C. Lower burning temperature of UTP Microwave Incinerator shows that by using this machine, the user can reduce cost and time burning the RHA.

4.1.4 X-Ray Fluorescence Analysis

X-Ray Fluorescence (XRF) test conducted to identify the chemical composition compound of RHA. Powder sample of 300 °C, 400 °C, 500 °C, 600 °C and 800 °C temperature burning of MIRHA tested. Table 4.1 shows the material contents inside MIRHA with different burning temperature.

Table 4.1 : Chemical composition of MIRHA with different burning temperature

Oxides	MIRHA (%) (300°C)	MIRHA (%) (400°C)	MIRHA (%) (500°C)	MIRHA (%) (600°C)	MIRHA (%) (800°C)
CaO	1.080	0.990	1.120	1.190	1.030
SiO_2	87.150	88.580	87.417	85.610	87.380
Al_2O_3	0.190	0.110	0.100	0.000	0.110
Fe_2O_3	0.400	0.264	0.125	0.248	0.151
Na_2O	0.000	0.000	0.000	0.000	0.000
K_2O	5.460	5.032	5.394	6.038	5.438
MgO	0.879	0.840	0.986	1.010	1.050
SO_3	0.617	0.425	0.525	0.692	0.621
CO_2	0.000	0.000	0.000	0.000	0.000
MnO	0.104	0.100	0.099	0.114	0.102
ZnO	0.037	0.022	0.023	0.049	0.026
Rb_2O	0.037	0.035	0.036	0.038	0.036
Cl	0.376	0.112	0.365	0.782	0.209
P_2O_5	3.670	3.490	3.810	4.230	3.850

Based on Table 4.1, SiO_2 is the main component in of the chemical component in RHA. This result is meet with the previous researcher had done [12] which is the silica content in RHA is between 80 – 95%. According to Andri, K. [17], the present of SiO2 and K2O will decrease the heat evolution in concrete hydration process. As a consequence, the concrete properties also will improve.

4.1.5 Scanning Electron Microscopy Analysis

After burn the MIRHA, the author sent the samples to conduct Scanning Electron Microscopy (SEM). This test is to see the microstructure of the sample. The samples are raw rice husk, MIRHA burn at 300 °C, 400 °C, 500 °C, 600 °C and 800 °C. Figure 4.4 shows microstructure of raw rice husk before burning. In Figure 4.5, shows the microstructure for different burning temperature of MIRHA. Comparing the microstructure of raw rice husk and rice husk ash after burning and grinding, the structure of MIRHA is finer than the raw rice husk.

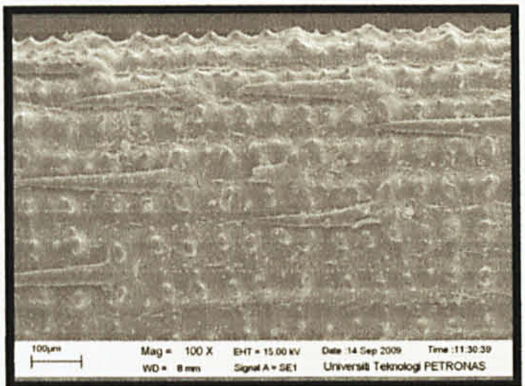

Figure 4.4 : Microstructure for raw rice husk

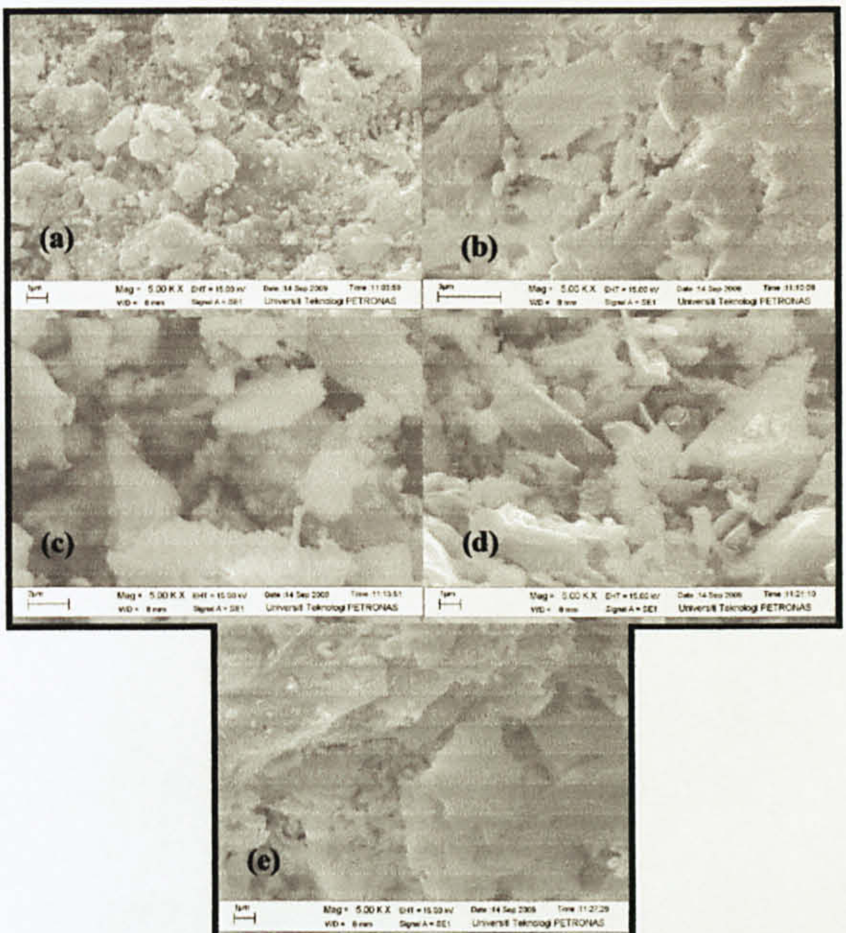

Figure 4.5 : Microstructure for MIRHA at (a) 300 °C (b) 400 °C (c) 500 °C (d) 600 °C (e) 800 °C

4.2 Hydration Phenomena

After determining the optimum burning temperature of RHA, the author proceeds to other experiments which are compressive strength test and non-evaporable water test. These experiments were conducted to achieve the second objective of this research which is to ascertain the hydration characteristics of MIRHA in normal and foamed concretes. All the MIRHA used was taken from the optimum burning temperature 300 °C.

4.2.1 Normal Concrete

The author decided to varies water cement ratios (w/c) for normal concrete which are 0.42 and 0.8. This is because the author wanted to determine the suitable w/c for foamed concrete. For compressive strength test and non-evaporable water test, the concrete samples were tested at 3, 7, and 28 days. Figure 4.6 shows the compressive strength for w/c 0.42 and Figure 4.7 shows the compressive strength for w/c 0.8.

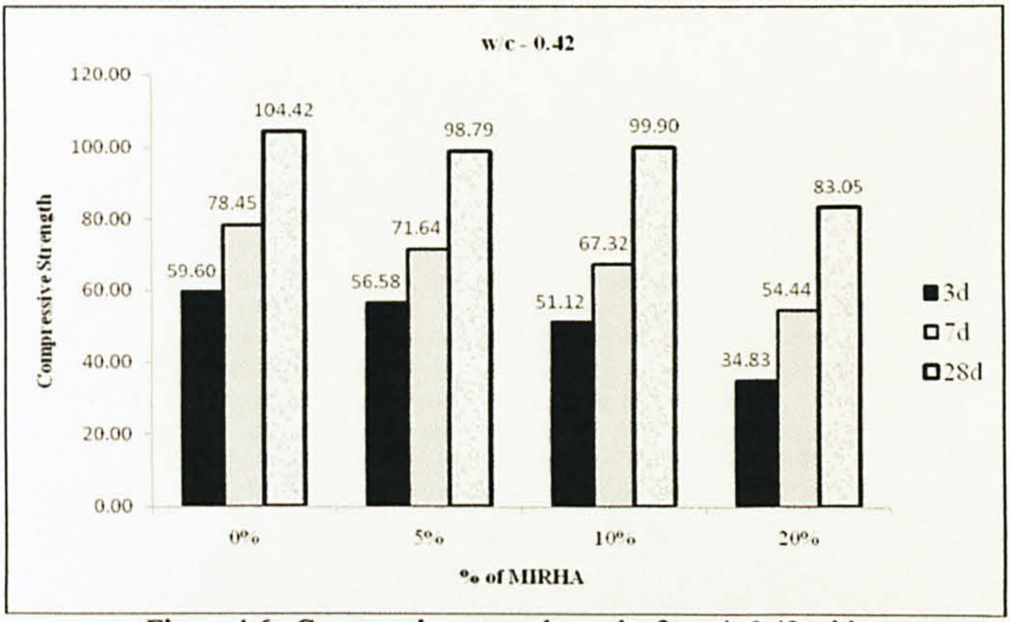

Figure 4.6 : Compressive strength results for w/c 0.42 with different percentage of MIRHA

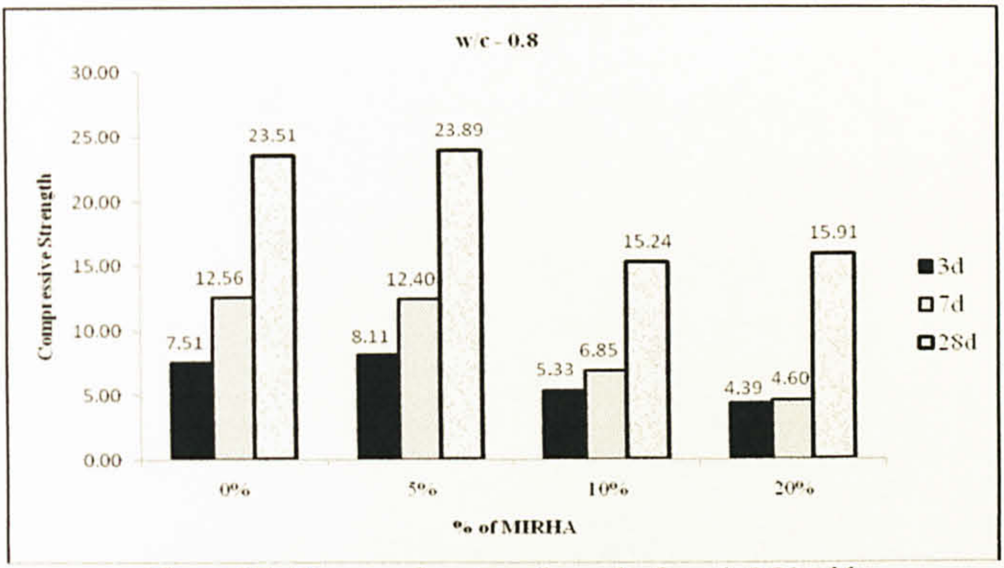

Figure 4.7 : Compressive strength results for w/c 0.80 with different percentage of MIRHA

Based on Figure 4.6 and 4.7 it showed that at early age the compressive strength is low. But after 7 days, the compressive strength was significantly inceased until reach 28 days. So, this proved that MIRHA is not an early strength material. The addition of MIRHA in concrete affected the compressive strength. When higher percentage of MIRHA was utilized, the compressive strength gradually decreased. This is because MIRHA have large surface area, so that it can absorb water in concrete. When high absorbtion occur, it will produced more void and increase the porosity of concrete. So, when porosity increased, the strength also will decreased.

Compressive strength of w/c of 0.42 was slightly higher than w/c of 0.80. The highest compressive strength for w/c of 0.42 was obtained when 0% of MIRHA was utilized. While for w/c of 0.8, the highest compressive strength obtained was when 5% of MIRHA was utilized.

Then, the author decided to determine the hydration characteristics of normal concrete based on non-evaporable water test. Figure 4.8 shows the hydration characteristics of normal concrete with w/c of 0.42 while Figure 4.9 shows the hydration characteristics of normal concrete with w/c of 0.80.

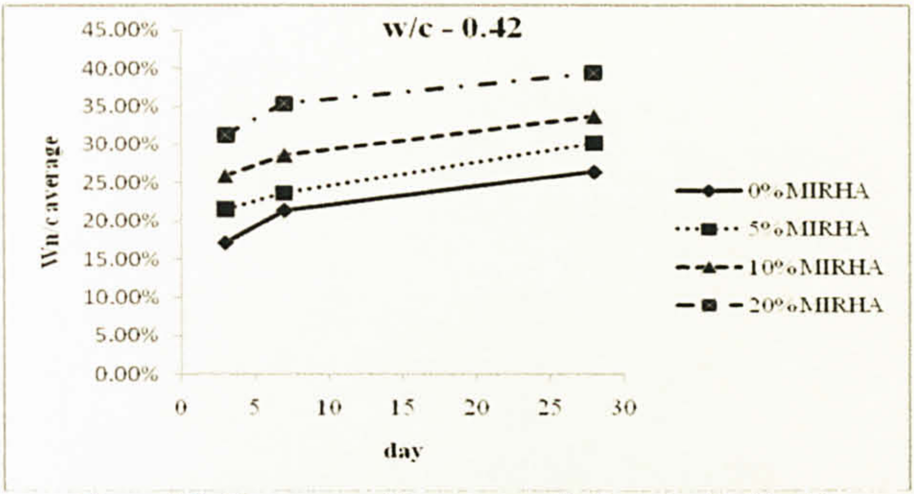

Figure 4.8 : Non-evaporable water results for w/c of 0.42 with different percentage of MIRHA

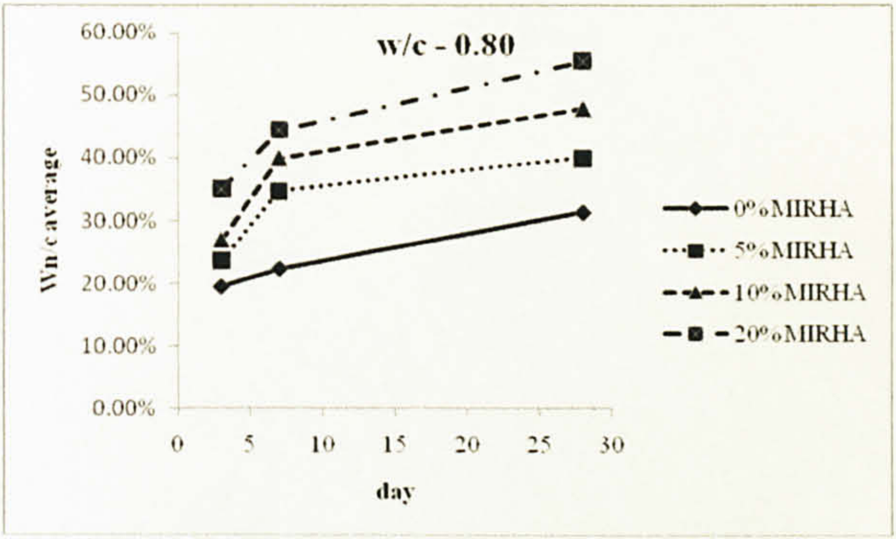

Figure 4.9 : Non-evaporable water results for w/c of 0.80 with different percentage of MIRHA

Based on both graphs non-evaporable water test, result for w/c of 0.80 is slightly higher than w/c of 0.42. Non-evaporable water test is used to determine the non-evaporable water content. Because of the water content in w/c of 0.80 is higher than w/c of 0.42, the hydration characteristics of normal concrete with w/c of 0.80 is proved to be higher than the w/c of 0.42. Both of these results shows that the highest non-evaporable water content is obtained when 20% of MIRHA added in the cement paste.

Because the compressive strength of w/c of 0.42 is slightly higher than 0.80, the author decided to use 0.42 w/c in the foamed concrete, in order to determine the highest strength of foam concrete.

4.2.2 Foamed concrete

The foamed concrete was tested at 3, 7, and 28 days. Figure 4.10 shows the compressive strength for foamed concrete.

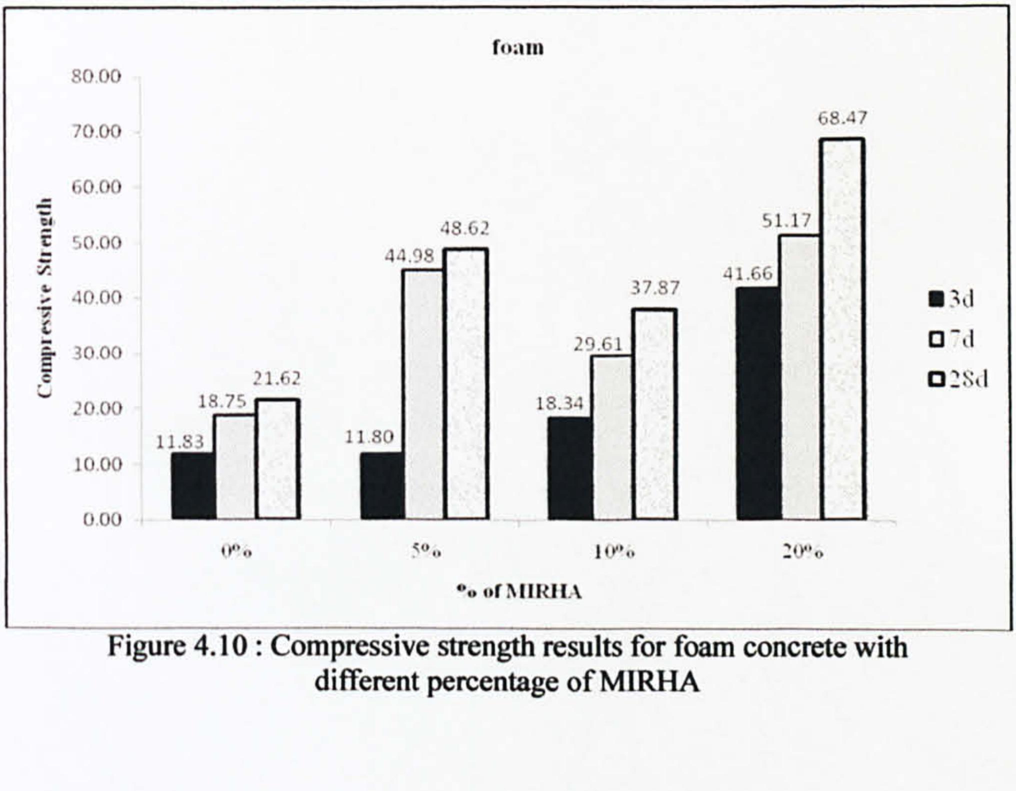

Figure 4.10 : Compressive strength results for foam concrete with different percentage of MIRHA

Similar with normal concrete, foam concrete also showed same characteristics which exhibit low strength on early days but the strength is increased after 7 days. In this case, it differs with normal concrete because the compressive strength of foamed concrete is approximately increased by increasing the percentage of MIRHA. The highest compressive strength for foamed concrete is obtained when 20% of MIRHA is incorporated in concrete. This is because foam itself has large voids and can easily evaporate while, MIRHA has fine structure. So, when MIRHA was added to foam, all voids in foam was filled by MIRHA. Therefore, when higher amount of MIRHA was added, the amount of voids will decrease and it will absorb water inside foam concrete. Hence, it will increase the strength of the concrete.

Then, the author used non-evaporable water test to determine the hydration characteristics for foamed concrete. Figure 4.11 shows the hydration characteristics of foamed concrete.

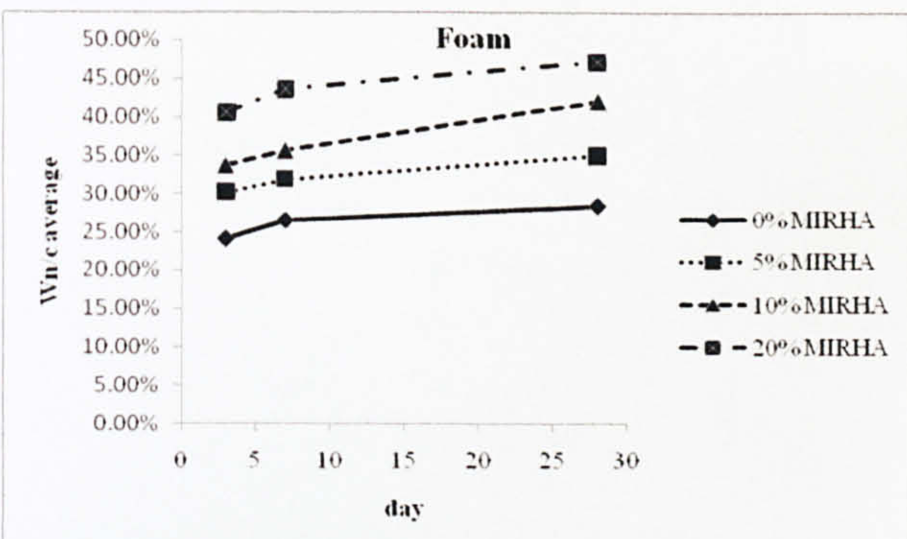

Figure 4.11 : Non-evaporable water results for foamed concrete with different percentage of MIRHA

Based on this graph, the highest non-evaporable water content for foam concrete is obtained when 20% of MIRHA was added in the cement paste. The amount of voids will decrease when the amount of MIRHA added also increase and it will easily to evaporate. Hence, it promoted the hydration process of foam concrete.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5. CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

In this chapter, the author concludes this research about the hydration characteristics of MIRHA in normal and foamed concrete. In addition, the author also provide some recommendation for future work.

5.1 Conclusion

This research was carried out to identify the optimum burning temperature for UTP Microwave Incinerator and to ascertain the hydration characteristics of MIRHA in normal and foamed concrete. The utilization of Microwave Incinerator Rice Husk Ash (MIRHA) into normal and foamed concretes gives various hydration characteristics. The following conclusions can be drawn from the study :

1. UTP Microwave Incinerator is one of the methods to burn rice husk and this method is a controlled burning. Different types of at temperature 300 °C, 400 °C, 500°C, 600 °C and 800 °C were tested using XRD, Compressive Strength, XRF and SEM. The optimum burning temperature for UTP Microwave Incinerator was found to be at 300 °C.

2. The optimum burning temperature of MIRHA used to identify the compressive strength and hydration characteristics of normal and foamed concrete. The highest compressive strength for normal concrete with 0.42 w/c was when no MIRHA added in the concrete while for w/c of 0.80, 5% of MIRHA added in the concrete was the highest. Comparing the hydration characteristics for normal concrete, the w/c of 0.80 shows the highest non-

evaporable water content than w/c of 0.42. This is because the water content in 0.80 is higher than the w/c of 0.42.

3. For foamed concrete, the highest compressive strength and non-evaporable water content at 28 days were obtained at 20% MIRHA concrete samples. This shows that the hydration and pozzolanic processes influenced the compressive strength of the concrete.

5.2 Recommendations for Future Research

To improve this research in future, the author had identify some recommendation. These are the recommendations that the other researchers need to be done :

1. Use burning temperature between 200 – 300 °C because in this research, the optimum temperature is at 300 °C. Maybe there is another optimum temperature below 300 °C. The lowest temperature to burn the MIRHA, the lowest the cost and time to produce RHA.

2. Because of the optimum corporation of MIRHA in foamed concrete is 20%, the author recommended that use more amount of MIRHA in foamed concrete so that the other researcher determine whether the the researchers can determine the optimum corporation of MIRHA if more than 20% of MIRHA added in foamed concrete.

CHAPTER 6
ECONOMIC BENEFITS

6. PROGRAMME OF WORK

In this chapter, the author will describe the costs used in this research. The author will explained on how to calculate the costs used in this research.

6.1 Cost Used to Determine Optimum Temperature of MIRHA

The main material that the author used is rice husk from rice milling plant, Malaysia. Cost per tonne for rice husk is RM 2500. 22% of paddy milled will produced husk and when this husk is burnt, only 25% of husk will produce ash. In this research, the author used approximately 50kg of rice husk for each burning temperature. The temperature used by the author are 300 °C, 400 °C, 500 °C, 600 °C and 800 °C.

Total rice husk used	=	50 kg x 5
	=	250 kg
Total rice husk ash	=	250 kg x 25%
	=	62.5 kg
Total price	=	250 kg x RM 2500/tonne
	=	RM 625

Table 6.1 : Cost used to determine optimum temperature of MIRHA

Material	Material Used (kg)	Price per Unit (RM)	Total Price (RM)
Cement	6.19	17/50kg	2.10
Dry fine aggregate	18.564	40/tonne	0.74
MIRHA	0.565	10/kg	5.65
Superplasticizer	0.275	N/A	N/A
Total			**8.49**

6.2 Cost Used to Determine Hydration Characteristics for Normal and Foamed Concrete

6.2.1 Normal Concrete

Table 6.2 : Cost used for normal concrete

Material	Material Used (kg)	Price per Unit (RM)	Total Price (RM)
Cement	12.833	17/50kg	4.36
MIRHA	1.231	10/kg	12.31
	Total		**16.67**

6.2.2 Foamed Concrete

For foam concrete, foam was produced by adding 300ml of water to 10ml of foam agent (based on ratio for foam agent and water is 1:30). Cost for foam agent is RM 20/liter.

Table 6.3 : Cost used for foamed concrete

Material	Material Used	Price per Unit (RM)	Total Price (RM)
Cement	6.19 kg	17/50kg	2.10
MIRHA	0.565 kg	10/kg	5.65
Foam	10 ml	20/L	0.20
	Total		**7.95**

6.3 Total Cost

Total cost for this research = RM (8.49 + 16.67 + 7.95)

= **RM 33.11**

So, the total cost for this research is approximately RM 33.11.

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APPENDICES

APPENDIX A

* Results for Burning Process

Temperature target : 300 °C

Initial temperature : 27.4 °C

Red light on at 240 min

Yellow light off at 254 min

Time	Time (min)	Temperature (°C)
09:55	0	27.4
10:55	60	39.3
11:55	120	47.6
12:55	180	56.6
13:44	229	69
13:55	240	136.2
13:58	243	158
13:59	244	180
14:00	245	190
14:01	246	201
14:02	247	206.3
14:04	249	209.2
14:05	250	211.8
14:06	251	230.4
14:07	252	248.5
14:08	253	279.3
14:09	254	295.3
14:10	255	307
14:11	256	319.1
14:13	258	336.6
14:14	259	347.2
14:15	260	353
14:16	261	358
14:17	262	361.4
14:18	263	370.5
14:19	264	393.3
14:20	265	419
14:21	266	432.8
14:22	267	439
14:25	270	440.2
14:26	271	438.5
14:27	272	435.3
14:43	288	423.3
14:44	289	427.8
14:45	290	444.3
14:46	291	457.7
14:47	292	470.8
14:48	293	479.3
14:58	303	591.8
15:11	316	587.7
15:22	327	582.2
15:25	330	573
15:55	360	530
16:35	400	461.3
16:40	405	446
16:45	410	437.6
16:50	415	428.6
16:55	420	422.5
17:00	425	418.2
17:05	430	409.7

Temperature target : 400 ^oC

Initial temperature : 37.8 ^oC

Red light on at 192 min

Yellow light off at 202 min

Time	Time (min)	Temperature (^oC)
09:10	0	37.8
10:10	60	50.8
11:10	120	58.1
12:10	180	70.4
12:20	190	83.1
12:23	193	148
12:24	194	155.6
12:25	195	170.6
12:26	196	184.5
12:27	197	200.8
12:28	198	210.6
12:29	199	258
12:30	200	311.3
12:31	201	374.9
12:32	202	409.5
12:33	203	434.6
12:34	204	441.4
12:35	205	442.4
12:37	207	443.5
12:40	210	459
12:45	215	474.2
12:50	220	485.5
12:55	225	480.1
13:00	230	476.8
13:05	235	486.1
13:10	240	544.2
13:11	241	558
13:12	242	565.4
13:13	243	572.3
13:14	244	578.5
13:15	245	590
13:16	246	612.2
13.17	247	653
13:18	248	669
13:19	249	664.1
13:20	250	651.3
13:21	251	640.5
13:22	252	631.5
13:25	255	618.2
13:26	256	616.6
13:29	259	611.7
13:30	260	609.4
14:00	290	555.8
14:51	341	529.3
15:14	364	522.9
16:14	424	488.9
16:20	430	481.9
16:30	440	467.3
16:40	450	454.8
16:50	460	436
17:00	470	420

Temperature target : 500 °C

Initial temperature : 34.8 °C

Red light on at 185 min

Yellow light off at 237 min

Time	Time (min)	Temperature (°C)
09:23	0	34.8
10:23	60	47.9
11:23	120	58.3
12:23	180	73.1
12:28	185	82.2
12:29	186	116.3
12:29:30	186.5	137.5
12:30	187	154.5
12:30:30	187.5	167.6
12:31	188	178.2
12:31:30	188.5	186.3
12:32	189	191.5
12:32:30	189.5	196.1
12:33	190	199.9
12:33:30	190.5	202.9
12:34	191	205.9
12:34:30	191.5	208.7
12:35	192	211.5
12:35:30	192.5	214.1
12:36	193	216.4
12:36:30	193.5	218.8
12:37	194	220.8
12:37:30	194.5	222.8
12:38	195	225
12:38:30	195.5	227.1
12:39	196	233.2
12:39:30	196.5	250.9
12:40	197	269.2
12:40:30	197.5	288.8
12:41	198	304.9
12:41:30	198.5	317.7
12:42	199	327.8
12:42:30	199.5	337.2
12:43	200	346
12:43:30	200.5	353.9
12:44	201	360.4
12:44:30	201.5	366.7
12:45	202	373.5
12:45:30	202.5	380.6
12:46	203	387.7
12:46:30	203.5	394.8
12:47	204	401.1
12:47:30	204.5	406.1
12:48	205	409.2
12:48:30	205.5	411.9
12:49	206	413.2
12:49:30	206.5	413
12:50	207	413.4
12:50:30	207.5	417.1
12:51	208	420.4
12:51:30	208.5	424.4
12:52	209	428
12:52:30	209.5	430.9
12:53	210	434
12:53:30	210.5	436.8
12:54	211	437.5
12:54:30	211.5	439.1
12:55	212	441
12:55:30	212.5	443
12:56	213	444.7
12:56:30	213.5	446.7
12:57	214	449.3
12:57:30	214.5	452
12:58	215	454.8
12:58:30	215.5	458
12:59	216	462
12:59:30	216.5	464.9
13:00	217	467
13:00:30	217.5	468.4
13:01	218	468.6
13:01:30	218.5	468.3
13:02	219	468.4
13:02:30	219.5	467
13:03	220	467.6

13:03:30	220.5	468.4
13:04	221	468.1
13:04:30	221.5	467.5
13:05	222	466.8
13:05:30	222.5	466.2
13:06	223	465.4
13:06:30	223.5	464.1
13:07	224	463.1
13:07:30	224.5	461.9
13:08	225	461.7
13:08:30	225.5	460
13:09	226	459.2
13:11	228	453
13:15	232	458
13:16	233	462.3
13:17	234	465.9
13:18	235	474.8
13:18:30	235.5	480.4
13:19	236	486.1
13:19:30	236.5	492.1
13:20	237	498.8
13:20:11	237.183	500.1
13:20:30	237.5	505.4
13:21	238	511
13:21:30	238.5	516.7
13:22	239	521.6
13:23	240	527.2
13:25	242	535.7
13:27	244	586
13:30	247	614.8
13:31	248	613.8
13:33	250	604.6
13:35	252	596.7
13:36	253	593.5
13:37	254	589.8
13:38	255	585.5
13:39	256	581.1
13:40	257	576.9
13:42	259	570.2
13:46	263	563.9
13:48	265	563.7
13:50	267	563.4
13:55	272	555.9
14:00	277	549.5
14:05	282	545.3
14:10	287	552.5
14:15	292	552
14:20	297	542.9
14:25	302	536.5
14:30	307	528.1

Temperature target : 600 °C

Initial temperature : 26.6 °C

Red light on at 220 min

Yellow light off at 271 min

Time	Time (min)	Temperature (°C)
09:12	0	26.6
10:12	60	41.2
11:12	120	50.8
12:19	187	64
12:38	206	72.1
12:43	211	78.9
12:45	213	82.7
12:47	215	86.7
12:50	218	93.3
12:51	219	94.3
12:52	220	97.7
12:53	221	118.6
12:53:30	221.5	140.8
12:54	222	159
12:54:30	222.5	176.6
12:55	223	192.6
12:55:30	223.5	205.5
12:56	224	217.2
12:57	225	235.1
12:57:30	225.5	241.5
12:58	226	246.3
12:58:30	226.5	250.8
12:59	227	254.9
12:59:30	227.5	260.3
13:00	228	266.8
13:01	229	285.8
13:01:30	229.5	296.8
13:02	230	308.7
13:02:30	230.5	315.5

13:03	231	323.7
13:04	232	338.3
13:04:30	232.5	345.7
13:05	233	352.1
13:05:30	233.5	360.3
13:06	234	369
13:06:30	234.5	378.9
13:07	235	388.1
13:07:30	235.5	397.6
13:08	236	405.9
13:08:30	236.5	413
13:09	237	420.2
13:09:30	237.5	426.4
13:10	238	432.2
13:10:30	238.5	437
13:11	239	441.6
13:12	240	452.4
13:12:30	240.5	457.4
13:13	241	462.9
13:14	242	474.8
13:15	243	485.6
13:16	244	499.3
13:17	245	510.1
13:18	246	517.6
13:19	247	522.5
13:20	248	525.3
13:21	249	527.3
13:25	253	523.5
13:30	258	514.6
13:33	261	512
13:35	263	515.7
13:36	264	518.4
13:38	266	522.5
13:40	268	554.5
13:41	269	572.6
13:42	270	585.8
13:43	271	596.1
13:44	272	603.9
13:45	273	607.2
13:50	278	645.7
13:55	283	690.1
14:00	288	686.3
14:05	293	676.8
14:10	298	657.7
14:15	303	635.5
14:20	308	618.4
14:25	313	607.9
14:30	318	597.5

Temperature target : 800 ^oC

Initial temperature : 27.1 ^oC

Red light on at 211 min

Time	Time (min)	Temperature (^oC)
09:21	0	27.1
10:21	60	40.8
11:35	134	55.3
11:56	155	58.4
11:58	157	61
12:04	163	62.4
12:12	171	64.3
12:21	180	66.8
12:28	187	68.4
12:42	191	73.6
12:45	194	75.6
12:50	199	79.8
12:51	200	80.4
12:52	201	81.5
12:53	202	104.8
12:53:30	202.5	132.8
12:54	203	156.5
12:54:30	203.5	176.5
12:55	204	192.8
12:55:30	204.5	205.4
12:56	205	216.6
12:56:30	205.5	225.6
12:57	206	233.6
12:57:30	206.5	239.7
12:58	207	246.6
12:58:30	207.5	253.3
12:59	208	261
12:59:30	208.5	268.2
13:00	209	276
13:00:30	209.5	283.9
13:01	210	291.8

13:01:30	210.5	305.4
13:02	211	323.7
13:02:30	211.5	342.1
13:03	212	358
13:03:30	212.5	370.6
13:04	213	381.9
13:04:30	213.5	392.8
13:05	214	401.8
13:05:30	214.5	409.8
13:06	215	417.2
13:06:30	215.5	423.3
13:07	216	428.6
13:07:30	216.5	433.6
13:08	217	438.6
13:10	219	456.1
13:10:30	219.5	460.1
13:11	220	463.9
13:11:30	220.5	467.7
13:12	221	471.3
13:12:30	221.5	474.9
13:13	222	477.6
13:13:30	222.5	480.3
13:14	223	482.3
13:14:30	223.5	484.1
13:15	224	485.6
13:16	225	487.1
13:17	226	490.4
13:19	228	490.8
13:20	229	490.7
13:21	230	491.2
13:22	231	491
13:23	232	491
13:24	233	490.7
13:25	234	490.6
13:26	235	490.6
13:27	236	490.2
13:27:30	236.5	488.4
13:28	237	488.5
13:29	238	488.2
13:30	239	488.8
13:31	240	488.5
13:32	241	487.9
13:33	242	486.8
13:34	243	485.2
13:35	244	482.7
13:36	245	481.2
13:37	246	479.9
13:38	247	481.1
13:38:30	247.5	484.9
13:39	248	488.8
13:39:30	248.5	494.4
13:40	249	500.1
13:40:30	249.5	505.8
13:41	250	510.8
13:41:30	250.5	516.2
13:42	251	521.5
13:42:30	251.5	526.5
13:43	252	530.1
13:43:30	252.5	532.7
13:44	253	535
13:45	254	544.9
13:46	255	564.8
13:46:30	255.5	572.5
13:47	256	580
13:47:30	256.5	588.6
13:48	257	596.2
13:48:30	257.5	604.3
13:49	258	612.3
13:49:30	258.5	619.1
13:50	259	624.6
13:50:30	259.5	628.5
13:51	260	631.7
13:51:30	260.5	634.7
13:52	261	637.8
13:52:30	261.5	640.3
13:53	262	642.8
13:53:30	262.5	646.3
13:54	263	648.3
13:54:30	263.5	648.5
13:55	264	648.7
13:55:30	264.5	648.5
13:56	265	648.6
13:56:30	265.5	648.6
13:57	266	649.1
13:57:30	266.5	647.7
13:58	267	649
13:58:30	267.5	650.1
13:59	268	652.8
13:59:30	268.5	655.8
14:00	269	658.5

14:00:30	269.5	660.2
14:01	270	661.8
14:01:30	270.5	663
14:02	271	663.8
14:02:30	271.5	665
14:03	272	665.6
14:03:30	272.5	666.1
14:04	273	666.2
14:04:30	273.5	665.8
14:05	274	664.6
14:05:30	274.5	663.6
14:06	275	662.4
14:06:30	275.5	661.8
14:07	276	662
14:07:30	276.5	661.9
14:08	277	662.1
14:08:30	277.5	662
14:09	278	661.9
14:10	279	660.8
14:11	280	657.3
14:12	281	653
14:13	282	648.8
14:14	283	644.8
14:15	284	642.1
14:18	287	632.7
14:20	299	625.7
14:25	304	607.9
14:30	309	599.3
14:35	314	585.1
14:40	319	575.9
14:45	324	581.9
14:50	329	577.1
14:56	335	569.4
15:03	542	549.6
15:11	550	535.1
15:15	554	530.1
15:26	565	523.9
15:30	569	519.8
15:34	573	516.5
15:44	583	512.7
16:00	599	514.6
16:07	606	514.4
16:15	614	515
16:21	620	514
16:30	629	517

APPENDIX B

Technical Specification for Microwave Incinerator Model Bentech Inc-21

Adapted from Bentech [27]

ITEM			DESCRIPTION
A	**GENERAL DESCRIPTION**		
	i)	Manufacturer	Pollution Engineering Sdn Bhd
	ii)	Model	BENTECH INC-21
	iii)	Capacity	1 m^3 Chamber
	iv)	Type of Waste	Paddy Husk
	v)	Overall Dimension (m)	2.3 (H) x 4.0 (W) x 4.0 (L)
	vi)	Operating Temperature	800 °C
	vii)	Emission & Ash Control System	Ceramic Filter
	viii)	Combustion Control	Temperature Controller
	ix)	Mode of Operation	PLC with Manual Overwrite
	x)	Mode of Loading	Manual
	xi)	Mode of Waste Ash Removal	Manual
B	**KILN CHAMBER**		
1	**Body Casing**		
	i)	Material and Thickness	SS 304 Plate Thickness 4.5 mm – 5.0 mm
	ii)	Support and Thickness	SS 304 Angle Iron 3 inch x 3 inch x t5.0 mm and above
2	**Charging Door**		
	i)	Dimension (mm) Big Door	580 x 455
	ii)	Dimension (mm) Small Door	315 x 315
C	**MICROWAVE INCINERATOR**		
	i)	Type	Air Cooled Magnetron
	ii)	Manufacturer/Model	Pollution Engineering Sdn Bhd/ MG-AIR 2450-1100
	iii)	Country of Origin	Malaysia
	iv)	Power Rating (1/hr)	1100 W

D	**THERMOCOUPLE**			
	i)	Length (mm)	300	450
	ii)	Type	In-Connel	
	iii)	Manufacturer/Brand	IPSH Sdn Bhd	
	iv)	Country of Origin	Malaysia	
	v)	Temperature Range	Up to 1600 °C	
E	**SUPPLY AIR BLOWER**			
	i)	Type	TSB 50	
	ii)	Manufacturer/Brand	Fu-Tsu	
	iii)	Country of Origin	Taiwan	
	iv)	Motor rating	1.5 KW	
	v)	Air Capacity (m^3/min)	Not less than 1.87 m^3/min	
F	**CERAMIC FILTER**			
	i)	Type	CERAFIL XS-1000	
	ii)	Manufacturer/Brand	CERAFIL	
	iii)	Country of Origin	United Kingdom	
	iv)	Surface Area (m^2)	0.19	
G	**INDUCED DRAFT FAN**			
	i)	Type	HFD 3242 T	
	ii)	Manufacturer/Brand	Maxis Fan	
	iii)	Country of Origin	Malaysia	
	iv)	Motor Rating	4 HP	
	v)	Air Capacity (m^3/min)	Not less than 0.15 m^3/min	
H	**AIR COMPRESSOR**			
	i)	Type	TS 05 120 H	
	ii)	Manufacturer/Brand	ELGI	
	iii)	Country of Origin	India	
	iv)	Motor Rating	5 HP	
	v)	Air Capacity (m^3/min)	Not less than 24.6 m3/min at 10 kgf/cm2	

I	**CONTROL PANEL**		
	i)	Enclosure	IP54
	ii)	Model of Operation	Programmable Logic Control (PLC)
	iii)	Type of PLC	Omron or equivalent
	iv)	Type of Cubicle	MERLIN GERLIN
	v)	Type of Contractor	TELEMECANIQUE
	vi)	Type of Starter	TELEMECANIQUE
	vii)	Touch Screen	GT21 4.7 Inch Panasonic
J	**WIRING WORKS**		
	i)	Type of Wiring	PVC
	ii)	Type of Conduit/Cable Tray	Galvanized Conduit